# SCHEDULING OF FLEXIBLE MANUFACTURING SYSTEM BY USING GENETIC ALGORITHM AND TAGUCHI PHILOSOPHY

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***Abstract*: Scheduling in an FMS environment is more complex and difficult than in a conventional manufacturing environment. Therefore, determining an optimal schedule and controlling an FMS is considered a difficult task. To achieve high performance for an FMS is, a good scheduling system should make a right decision at a right time according to system conditions. Flexible manufacturing system (FMS) scheduling problems become extremely complex when it comes to accommodate frequent variations in the part designs of incoming jobs. This research focuses on scheduling of variety of incoming jobs into the system efficiently and maximizing system utilization and throughput of system where machines are equipped with different tools and tool magazines but multiple machines can be assigned to single operation. Jobs have been scheduled according to shortest processing time (SPT) rule. Shortest processing time (SPT) scheduling rule is simple, fast, and generally a superior rule in terms of minimizing completion time through the system, minimizing the average number of jobs in the system, usually lower in-process inventories (less shop congestion) and downstream idle time (higher resource utilization). Simulation is better than experiment with the real-world system because the system as yet does not exist and experimentation with the system is expensive, too time consuming, too dangerous. In this research, Taguchi philosophy and genetic algorithm have been used for optimization. Genetic algorithm (GA) approach is one of the most efficient algorithms that aim at converging and giving optimal solution in a shorter time. Therefore, in this work, a suitable fitness function is designed to generate optimum values of factors affecting FMS objectives (maximization of system utilization and maximization of throughput of the system by Genetic Algorithm approach).**

***Keywords*: Flexible manufacturing system, shortest processing time, GA, SPT**

## I. Introduction

In today's competitive global market, manufacturers have to modify their operations to ensure a better and faster response to needs of customers. The primary goal of any manufacturing industry is to achieve a high level of productivity and flexibility which can only be done in a computer integrated manufacturing environment. A flexible manufacturing system (FMS) is an integrated computer-controlled configuration in which there is some amount of flexibility that allows the system to react in the case of changes, whether predicted or unpredicted. FMS consists of three main systems. The work machines which are often automated CNC machines are connected by a material handling system(MHS) to optimize parts flow and the central control computer which controls material movements and machine flow. An FMS is modeled as a collection of workstations and automated guided vehicles (AGV). It is designed to increase system utilization and throughput of system and for reducing average work in process inventories and many factors affects both system utilization and throughput of system in this research system utilization and throughput of system has been optimized considering factors, which is discussed in next section.

### 1.1 Flexible manufacturing system

A system that consists of numerous programmable machine tools connected by an automated material handling system and can produce an enormous variety of items. A FMS is large, complex, and expensive manufacturing in which Computers run all the machines that complete the process so that many industries cannot afford traditional FMS hence the trend is towards smaller versions call flexible manufacturing cells. Today two or more CNC machines are considered a Flexible Manufacturing Cell (FMC), and two or more cells are considered a Flexible Manufacturing System (FMS) **"**Flexible manufacturing system is a computer controlled manufacturing system, in which numerically controlled machines are interconnected by a material handling system and a master computer controls both NC machines and material handling system."[1] The primary goal of any manufacturing industry is to achieve a high level of throughput, flexibility and system utilization. System utilization computed as a percentage of the available hours (Number of the machines available for production multiplied by the number of working hours), it can be increased by changing in plant layout, by reducing transfer time between two stations and throughput, defined as the number of parts produced by the last machine of a manufacturing system over a given period of time. If the no of parts increases throughput also increases and also system utilization increases. Flexible manufacturing system consist following components

**Work station**: work station consist computer numerical controlled machines that perform various operations on group of parts. FMS also includes other work station like inspection stations, assembly works and sheet metal presses.

**Automated Material Handling and Storage system**: Work parts and subassembly parts between the processing stations are transferred by various automated material handling systems. Many automated material handling devices are used in flexible manufacturing system like automated guided vehicle, conveyors, etc. there are two types of material handling system.

**Primary handling system**- establishes the basic layout of the FMS and is responsible for moving work parts between stations in the system.
**Secondary handling system**- consists of transfer devices, automatic pallet changers, and similar mechanisms located at the workstations in the FMS.
**Computer Control System**: It is used to control the activities of the processing stations and the material handling system in the FMS.

### 1.2. Sequencing of jobs

The machines are arranged in a typical layout in a given FMS environment. The set of jobs are processed, those have different operations. According to their processing time, due dates these jobs scheduled to minimize make span. There are following rules selected from many existing priority scheduling rules to obtain optimum sequence.
**First-Come, First-Serve (FCFS*)*** - the job which arrives first, enters service first (local rule). It is simple, fast, and "fair" to the customer. And disadvantage of this rule is, it is least effective as measured by traditional performance measures as a long job makes others wait resulting in idle downstream resources and it ignores job due date and work remaining (downstream information).
**Shortest Processing Time (SPT)**- the job which has the smallest operation time enters service first (local rule). Advantages of this sequencing rule is simple, fast, generally a superior rule in terms of minimizing completion time through the system, minimizing the average number of jobs in the system, usually lower in-process inventories (less shop congestion) and downstream idle time (higher resource utilization), and usually lower average job tardiness and disadvantages is, it ignores downstream, due date information, and long jobs wait (high job wait-time variance). **Earliest Due Date (EDD)**- the job which has the nearest due date, enters service first (local rule) and it is simple, fast, generally performs well with regards to due date, but if not, it is because the rule does not consider the job process time. It has high priority of past due job and it ignores work content remaining.
**Critical Ratio (CR) Rule**- sequences jobs by the time remaining until due date divided by the total remaining processing time (global rule). The job with the smallest ratio of due date to processing time enters service first. The ratio is formed as (Due Date-Present Time)/Remaining Shop Time where remaining shop time refers to: queue, set-up, run, wait, and move times at current and downstream work centers. It recognizes job due date and work remaining (incorporates downstream information)but in this sequencing, past due jobs have high priority, does not consider the number of remaining operations.
**Slack Per Operation**- is a global rule, where job priority determined as (Slack of remaining operations) it recognizes job due date and work remaining (incorporates downstream information)
**Least Changeover Cost (Next Best rule)**- sequences jobs by set-up cost or time (local rule).it is simple, fast, generally performs well with regards to set-up costs. It does not consider the job process time, due date and work remaining.

### 1.3 Genetic algorithm

Genetic Algorithms (GA) are direct, parallel, stochastic method for global search and optimization, which imitates the evolution of the living beings, described by Charles Darwin. GA is part of the group of Evolutionary Algorithms (EA). The evolutionary algorithms use the three main principles of the natural evolution: reproduction, natural selection and diversity of the species, maintained by the differences of each generation with the previous.
Genetic Algorithms works with a set of individuals, representing possible solutions of the task. The selection principle is applied by using a criterion, giving an evaluation for the individual with respect to the desired solution. The best-suited individuals create the next generation. It optimizes with both continuous and discrete variables efficiently. It doesn't require any derivative information. It searches from a wide sampling of the cost surface simultaneously. It handles a large no. of variables at a time. It optimizes variables with extremely complex cost surfaces. It provides a list of optimum variables, not just a single solution. Genetic algorithm has following steps

1. Generate initial population – in most of the algorithms the first generation is randomly generated, by selecting the genes of the chromosomes among the allowed alphabet for the gene. Because of the easier computational procedure it is accepted that all populations have the same number (N) of individuals.
2. Calculation of the values of the function that we want to minimize of maximizes.
3. Check for termination of the algorithm – as in the most optimization algorithms, it is possible to stop the genetic optimization by:
4. Selection – between all individuals in the current population are chose those, who will continue and by means of crossover and mutation will produce offspring population. At this stage elitism could be used – the best n individuals are directly transferred to the next generation. The elitism guarantees, that the value of the optimization function cannot get worst (once the extreme is reached it would be kept).
5. Crossover – the individuals chosen by selection recombine with each other and new individuals will be created. The aim is to get offspring individuals that inherit the best possible combination of the characteristics (genes) of their parents
6. Mutation – by means of random change of some of the genes, it is guaranteed that even if none of the individuals contain the necessary gene value
7. New generation – the elite individuals chosen from the selection are combined with those who passed the crossover and mutation, and form the next generation. It works smoothly with both numerical and experimental data. It is well suited for parallel computing.

## II. METHODOLOGY

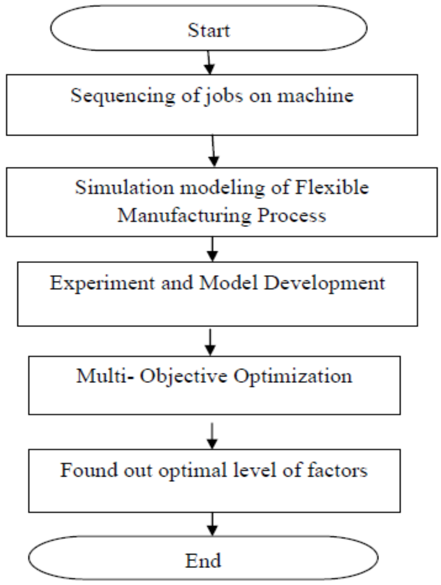


**Figure 1:** flow chart of analysis of jobs

In this research methodology has been adopted as shown in figure 1, it starts with scheduling of job by using sequencing rules, and then according to scheduling a simulated small flexible manufacturing has been developed. The process variables those affects FMS objectives were designed by using Taguchi philosophy has been treated as input function for simulation model of FMS to generate the throughput and working hours for each machine per year and then system utilization and throughput has been optimized as discussed below

## III. RESULTS AND DISCUSSIONS

### 3.1. Scheduling

In this research, Shortest Processing Time (SPT) has been used. In Shortest Processing Time (SPT), the job which has the smallest operation time enters service first (local rule). SPT rule is simple, fast, generally a superior rule in terms of minimizing completion time through the system, minimizing the average number of jobs in the system, usually lower in-process inventories (less shop congestion) and downstream idle time (higher resource utilization), and usually lower average job tardiness. Scheduling of flexible manufacturing system according to SPT rule is as shown in table 1. According to this sequence make span is 12 min.

**Table 1**: Sequencing of operation on jobs

| $M/C_k$ | Sequence of operation |
|---|---|
| $M/C_1$ | $O_{21}$-$O_{41}$-$O_{23}$ |
| $M/C_2$ | $O_{12}$-$O_{42}$-$O_{32}$ |
| $M/C_3$ | $O_{31}$ |
| $M/C_4$ | $O_{11}$- $O_{13}$-$O_{33}$-$O_{34}$ |
| $M/C_4$ | $O_{22}$ |

### 3.2. Experimental design

In this research L27 array has been used as discussed in previous chapter. When the process variable designed by using Taguchi philosophy has been treated as input function for simulation model of FMS to generate the working hours for every machine per year, and also gives the throughput of system. According to objective of FMS throughput and system utilization are larger is better. So using larger is better in L27 array in Taguchi philosophy following plots and regression equations obtained.

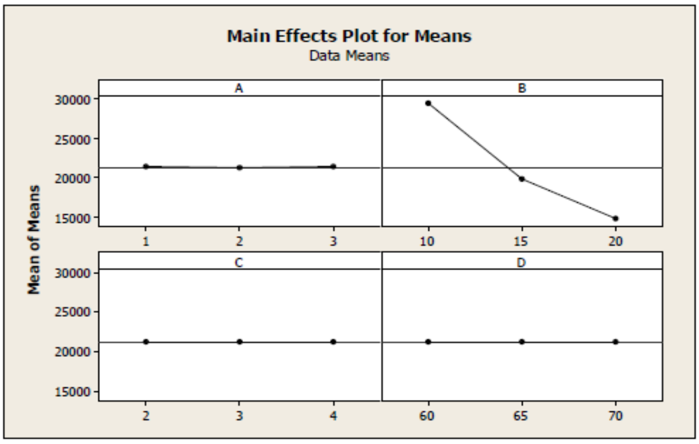


**Figure 2:** Main effect plot for means of throughput of system

Main effect plot for means of throughput shows that distance preference should be at first level means distance preference should be smallest for this simulated flexible manufacturing system for maximizing throughput of system and throughput of system is maximum at demand time is 10 min. and no. of carts is 4 and velocity of cart is 65 feet/min.

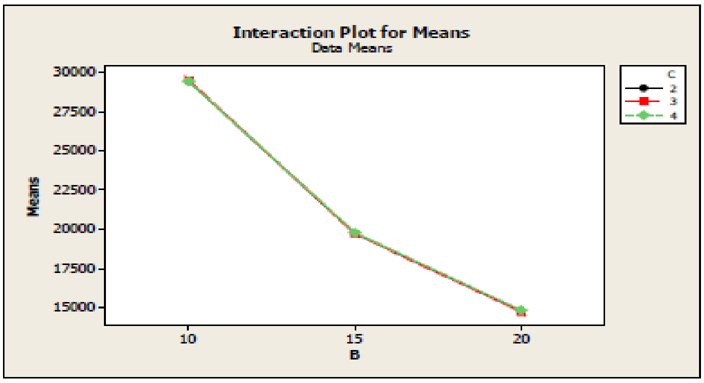


**Figure 3:** Interaction plots between demand arrival time (B) and no. of carts(C) for throughputInteraction plots for means between demand arrival demand time (B) and no. of carts (C) gives that as arrival demand time increases throughput of system decreases there is very less effect of no. of carts on throughput according to this research in this problem.

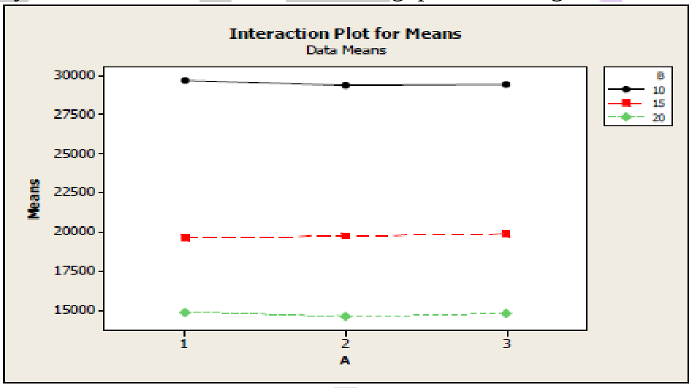


**Figure 4**: Interaction plots between and distance preference (A) and demand arrival time (B) for throughput

Interaction plots for means between demand arrival demand time (B) and distance preference (A) gives that as arrival demand time increases throughput of system decreases and when arrival demand time is 20 min., throughput maximum at level 1 means when the distance preference is smallest but when arrival demand time is 15 min., throughput maximum at level three means the distance preference is cyclical, and when arrival demand time is 10 min. and distance preference is smallest so throughput of system is maximum. It means as arrival time increases, throughput of system decreases

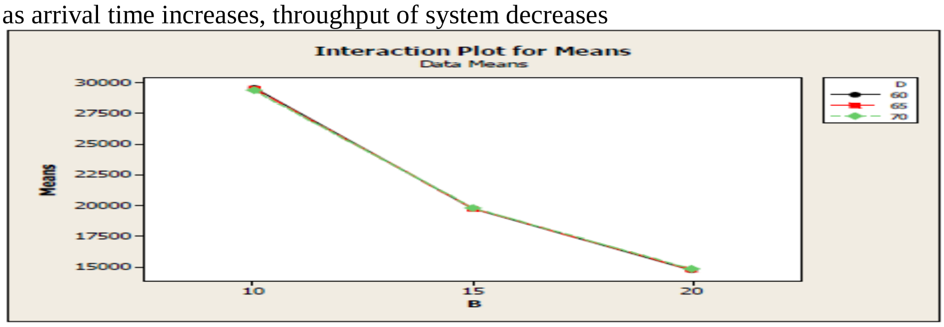


**Figure 5**: Interaction plots for means between demand arrival time (B) and velocity of carts (D) for system throughput.

Interaction plots for means between demand arrival demand time (B) and velocity of carts (D) gives that as arrival demand time increases throughput of system decreases there is very less effect of velocity of carts on throughput according to this research in this problem.

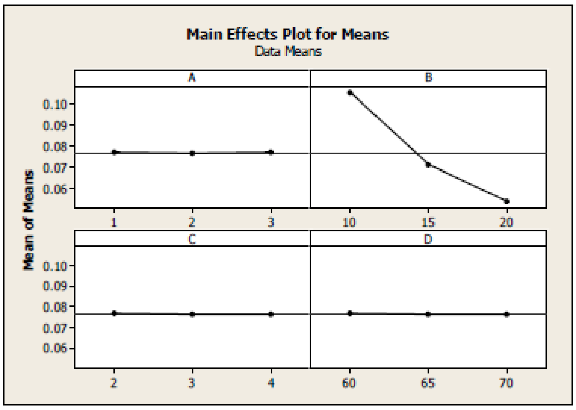


**Figure 6:** Main effect plot for means of system utilization

Main effect plot of system utilization shows that distance preference should be at first level means distance preference should be smallest for this simulated flexible manufacturing system for maximizing system utilization of system is maximum at demand time is 10 min. and no. of carts is 2 and velocity of cart is 60 feet/min.

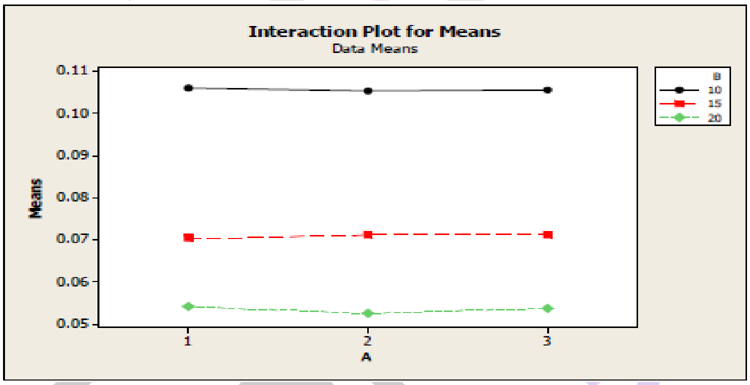


**Figure 7**: Interaction plots for means between and distance preference (A) and demand arrival time (B) for system utilization.

Interaction plots for means between demand arrival demand time (B) and distance preference (A) gives that as arrival demand time increases throughput of system decreases and when arrival demand time is 20 min., throughput maximum at level 1 means when the distance preference is smallest but when arrival demand time is 15 min., throughput maximum at level three means the distance preference is cyclical, and when arrival demand time is 10 min. and distance preference is smallest so throughput of system is maximum. It means as arrival time increases , throughput of system decreases

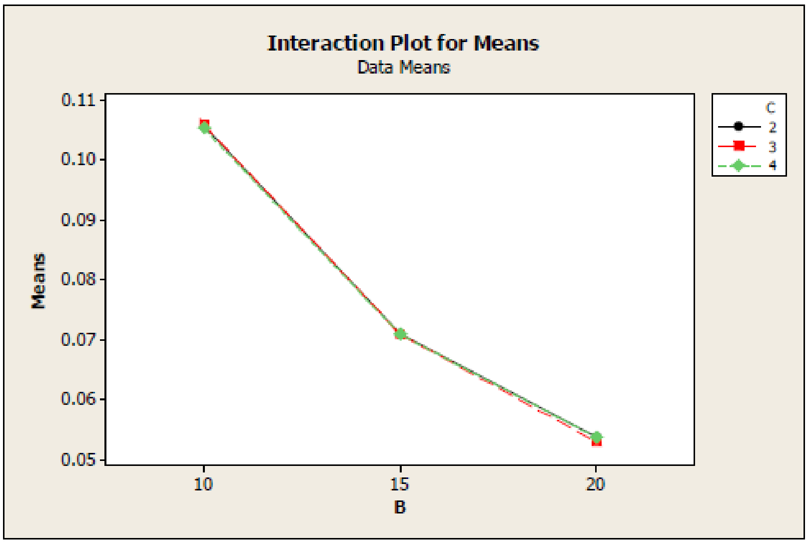


**Figure 8:** Interaction plots for means between demand arrival time (B) and no. of carts(C) for system utilization.

Interaction plots for means between demand arrival demand time (B) and no. of carts (C) gives that as arrival demand time increases throughput of system decreases there is very less effect of no. of carts on system utilization according to this research in this problem.

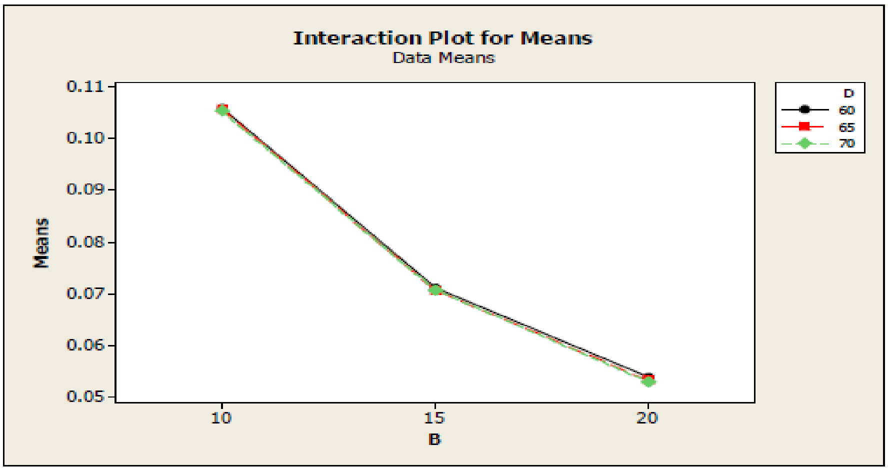


**Figure 9**: Interaction plots for means between demand arrival time (B) and velocity of carts (D) for system utilization.

Interaction plots for means between demand arrival demand time (B) and velocity of carts (D) gives that as arrival demand time increases throughput of system decreases there is very less effect of velocity of carts on throughput according to this research in this problem.

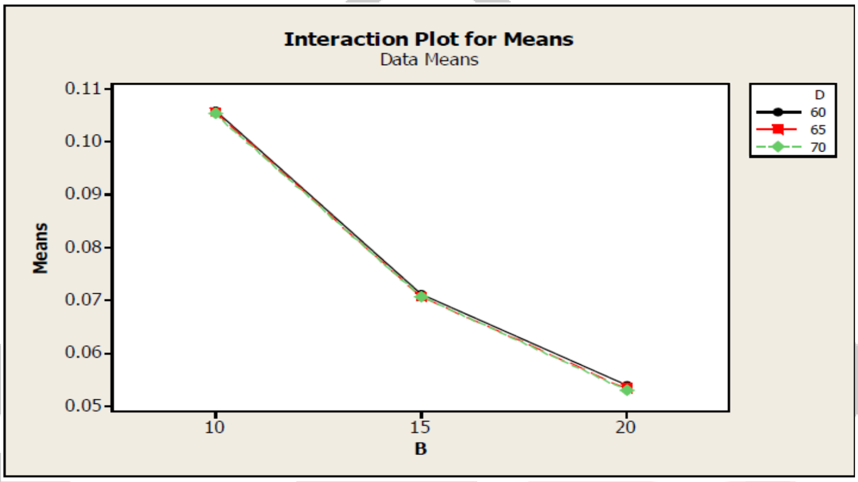


**Figure 10:** Interaction plots for means between demand arrival time (B) and velocity of carts (D) for system utilization.

As shown in response table for means gives that demand time is more influencing factor than other factors. Than velocity of carts affects the system utilization and distance preference is very less influencing factor for throughput.

**Table 2:** Response table for means for throughput

| Level | A | B | C | D |
|---|---|---|---|---|
| 1 | 0.07681 | 0.10573 | 0.07675 | 0.07697 |
| 2 | 0.07628 | 0.07086 | 0.07659 | 0.07659 |
| 3 | 0.07684 | 0.05334 | 0.0766 | 0.07638 |
| Delta | 0.00056 | 0.05239 | 0.00016 | 0.0006 |
| Rank | 3 | 1 | 4 | 2 |

As shown in response table for means gives that demand time is more influencing factor than other factors. Than velocity of carts affects the system utilization and distance preference is very less influencing factor for system utilization

**Table 3:** Response table for system utilization

| Level | A | B | C | D |
|---|---|---|---|---|
| 1 | 21373 | 29453 | 21295 | 21315 |
| 2 | 21235 | 19732 | 21318 | 21317 |
| 3 | 21340 | 14763 | 21334 | 21316 |
| Delta | 138 | 14690 | 39 | 2 |
| Rank | 2 | 1 | 3 | 4 |

### 3.3. Optimization

In this research, system throughput of system and system utilization both are optimized by genetic algorithm, using genetic algorithm following results obtained as shown in table 4 and table 5 respectively for maximum throughput = 43321 - 17*distance preferences (X1) - 1469 *arrival demand + 19* no. of carts (X3) + 0.1 * velocity of carts (X4)

**Table 4:** factor and their level for maximizing throughput through genetic algorithm

| Factors | Level | value |
|---|---|---|
| Distance Preference | Level1 | Smallest distance |
| Demand Arrival time | Level1 | 10 minutes |
| No. of carts | Level3 | 4 |
| Velocity of cart | - | 62.501 |

Throughput obtained by value of above factor in simulation is 30013. System utilization = 0.159 + 0.00001 *distance preferences (X1) - 0.00524*arrival demand time (X2) - 0.00007 * no. of carts (X3) - 0.000060 * velocity of carts (X4)

**Table 5:** factor and their level for maximizing system utilization through genetic algorithm

| Factors | Level | value |
|---|---|---|
| Distance Preference | Level1 | Smallest distance |
| Demand Arrival time | Level1 | 10 minutes |
| No. of carts | Level3 | 4 |
| Velocity of cart | - | 69.941 |

System utilization obtained by value of above factor in simulation is 0.1071% Apart from the single objective functions considered for this problem, a combined function is also used to perform the multi-objective optimization for the FMS parameters. The function and the variable limits are given using following function. Equal weights are considered for all the responses in this multi-objective optimization problem. Hence W1 and W2 are equal to 0.5.

$$Z_{Multi} = w_1 * \frac{Z_{system\ utilization}}{system\ utilizationa_{max}} + w_2 * \frac{Z_{throughput}}{Throughput_{max}}$$

Using above function a following combined function obtained which is optimized by using genetic algorithm and gives results as shown in table 6 $Z_{Multi}$ = 0.5 * (1.49155 - 0.0000938 * X(1) distance preferences - 0.049155 * X(2) arrival demand time + 0.0006566 * X(3) No. of carts + 0.0005628*X(4) Velocity of carts )-0.75*(1.4642 - 0.0005717 * X(1) distance preferences -0.49406 * X(2) arrival demand time +19 * X(3) No. of carts +0.0006390 * X(4) Velocity of carts ).

**Table 6:** Factor and their level for maximizing throughput and system utilization through Genetic algorithm.

| Factors | Level | value |
|---|---|---|
| Distance Preference | Level1 | Smallest distance |
| Demand Arrival time | Level1 | 10 minutes |
| No. of carts | Level3 | 4 |
| Velocity of cart | - | 62.495 |
| Throughput | - | 30018 |
| System utilization | - | 0.1085% |

## IV. CONCLUSIONS & FUTURE SCOPE

### 4.1 Conclusion

In this research, we presented a simulation modeling and optimization of FMS objectives for evaluating the effect of factors such as demand arrival time, no. of carts used in system, velocity of carts, and distance preference between two stations. System utilization and throughput both are affected by these factors. System utilization and throughput is more affected by demand arrival time comparatively other three factors. Distance preference also affects throughput and system utilization. For both system utilization and throughput distance preference should be smallest. And as the demand arrival time increases both system utilization and throughput of system decreases. No of carts and velocity of carts are less affected.

### 4.2 Future scope

The problems here solved are solved by following Genetic Algorithm. It is also observed that use of Genetic algorithm in integration with other meta heuristics like Tabu search, simulated annealing, neural networks to determine the optimized schedule in an FMS. It can also be solved by various other techniques such as particle Swarm Optimization and many others. Another approach can also be by following Adaptive Genetic Algorithm or by following higher Heuristic Approach. Generally, jobs are scheduled but simultaneous scheduling of jobs and machines remains the most interesting area to work on and this can do wonders to our industrial life. In this case, both, jobs and machines will work together and the make span time can be drastically reduced. It is also observed that use of Genetic algorithm in integration with other meta heuristics like Tabu search, simulated annealing, neural networks to determine the optimized schedule in an FMS.

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